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FEB 05 2004
PATENT & TRADEMARK OFFICE

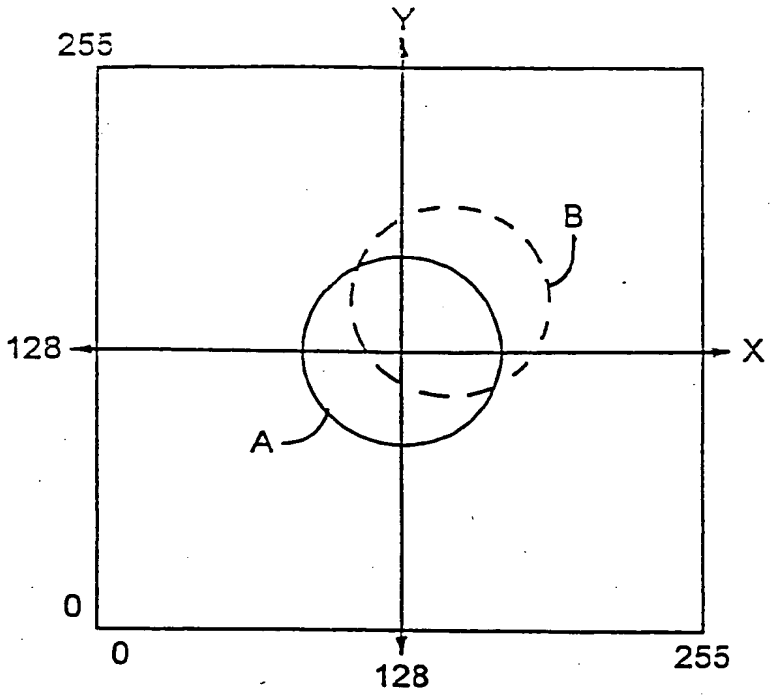


FIG. 1

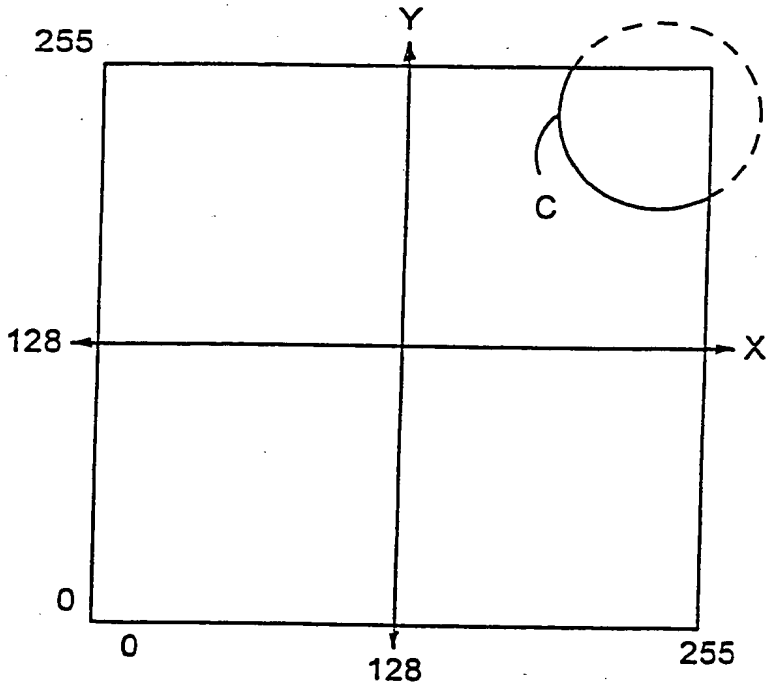


FIG. 2

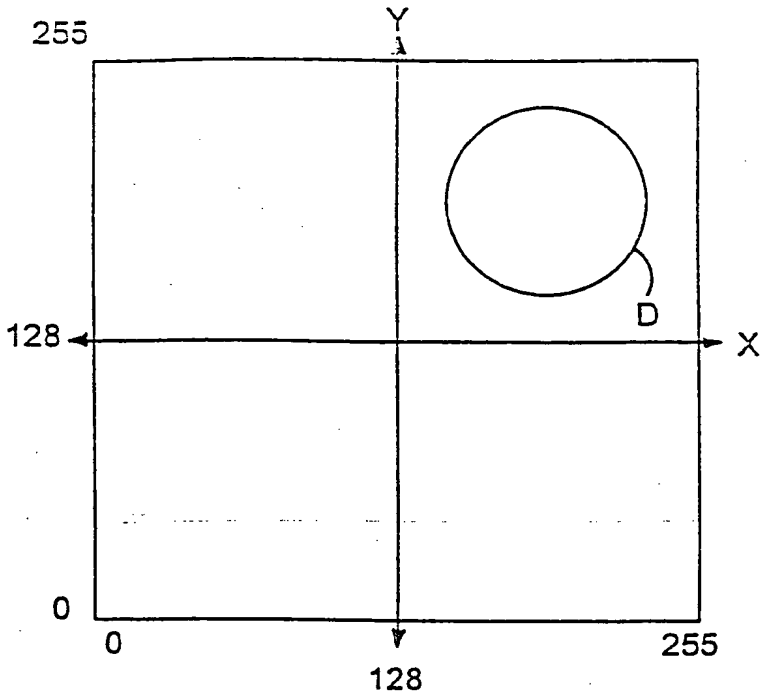

255
Y
128
X
D
0
0
255
128

FIG. 3

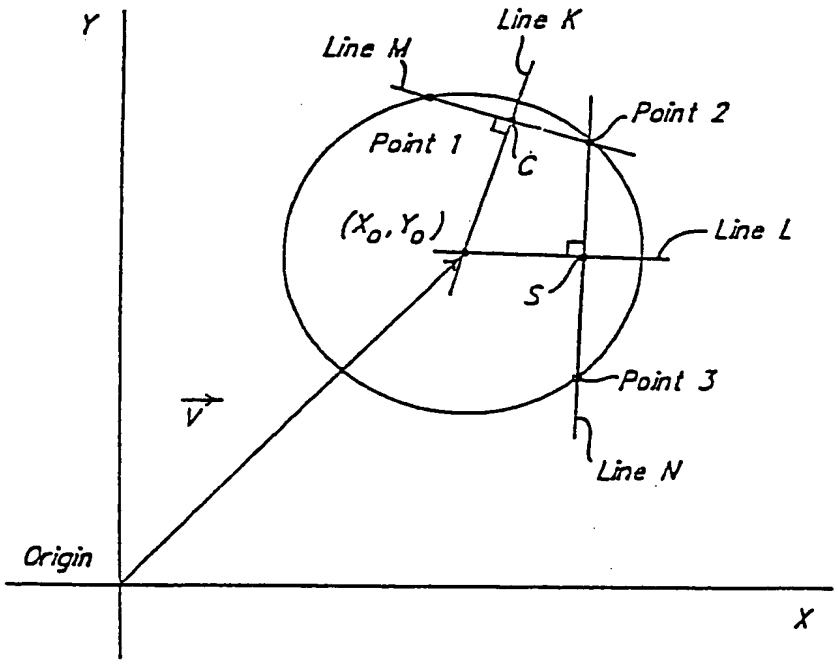

Y
Line M
Line K
Point 2
Point 1
C
(X_0, Y_0)
Line L
S
Point 3
$\vec{V}$
Line N
Origin
X

FIG. 5

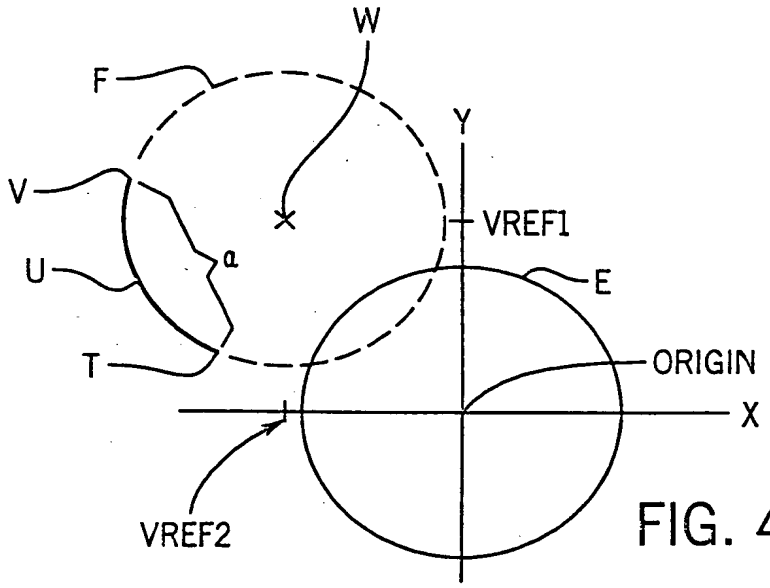


FIG. 4

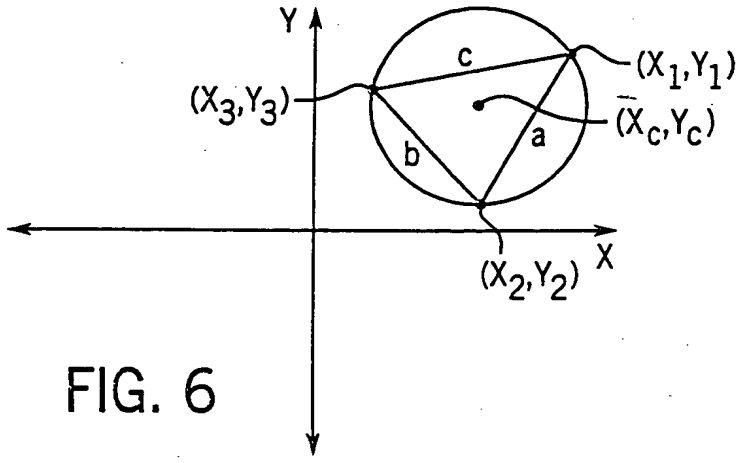


FIG. 6

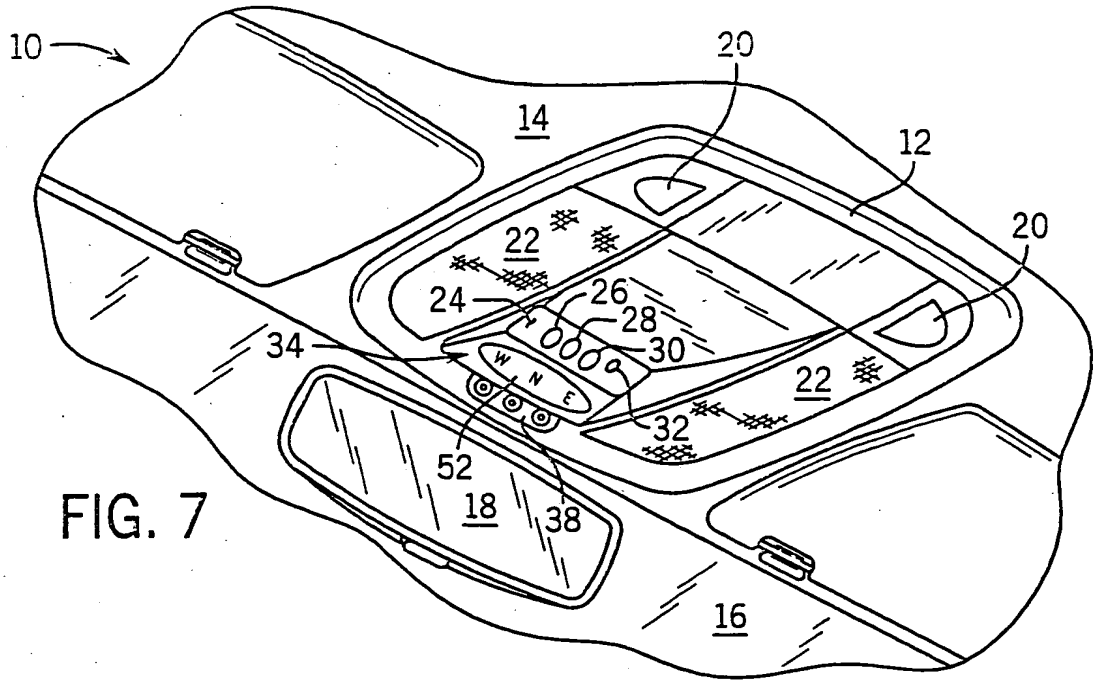

10
20
14
12
20
22
24
26
28
30
34
W
N
E
22
32
52
18
38
16

FIG. 7

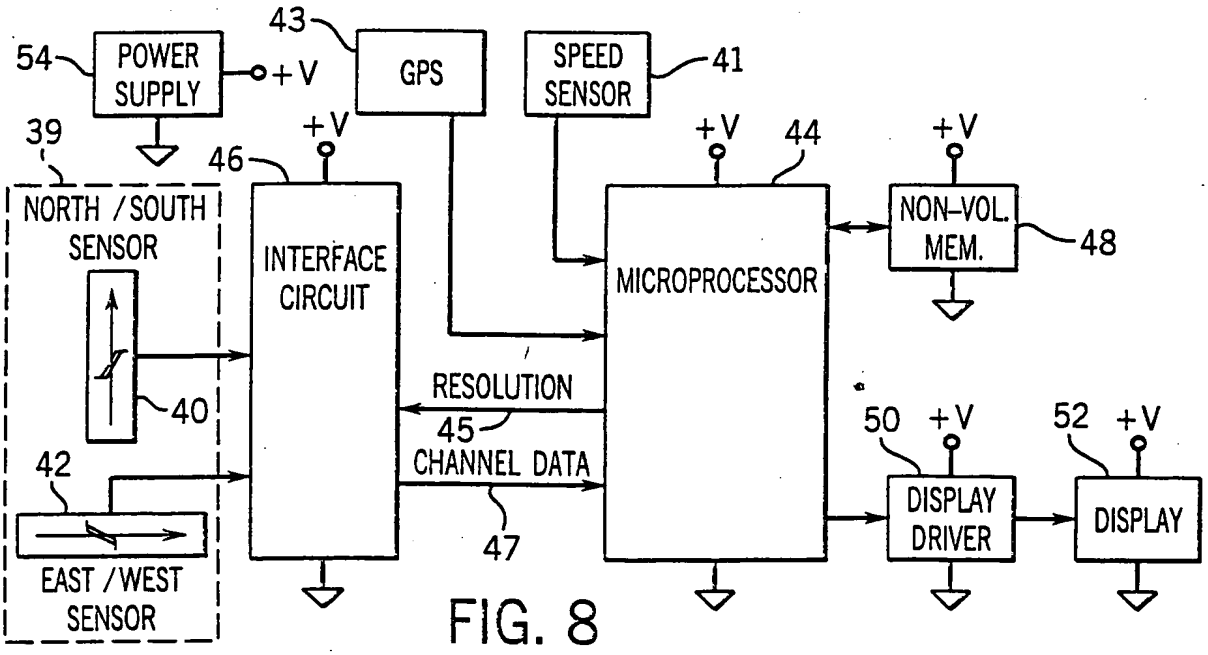

54
POWER SUPPLY
+V
43
GPS
SPEED SENSOR
41
39
+V
46
+V
44
+V
NORTH /SOUTH SENSOR
INTERFACE CIRCUIT
MICROPROCESSOR
NON-VOL. MEM.
48
40
RESOLUTION
45
CHANNEL DATA
50
+V
52
+V
42
DISPLAY DRIVER
DISPLAY
47
EAST /WEST SENSOR

FIG. 8

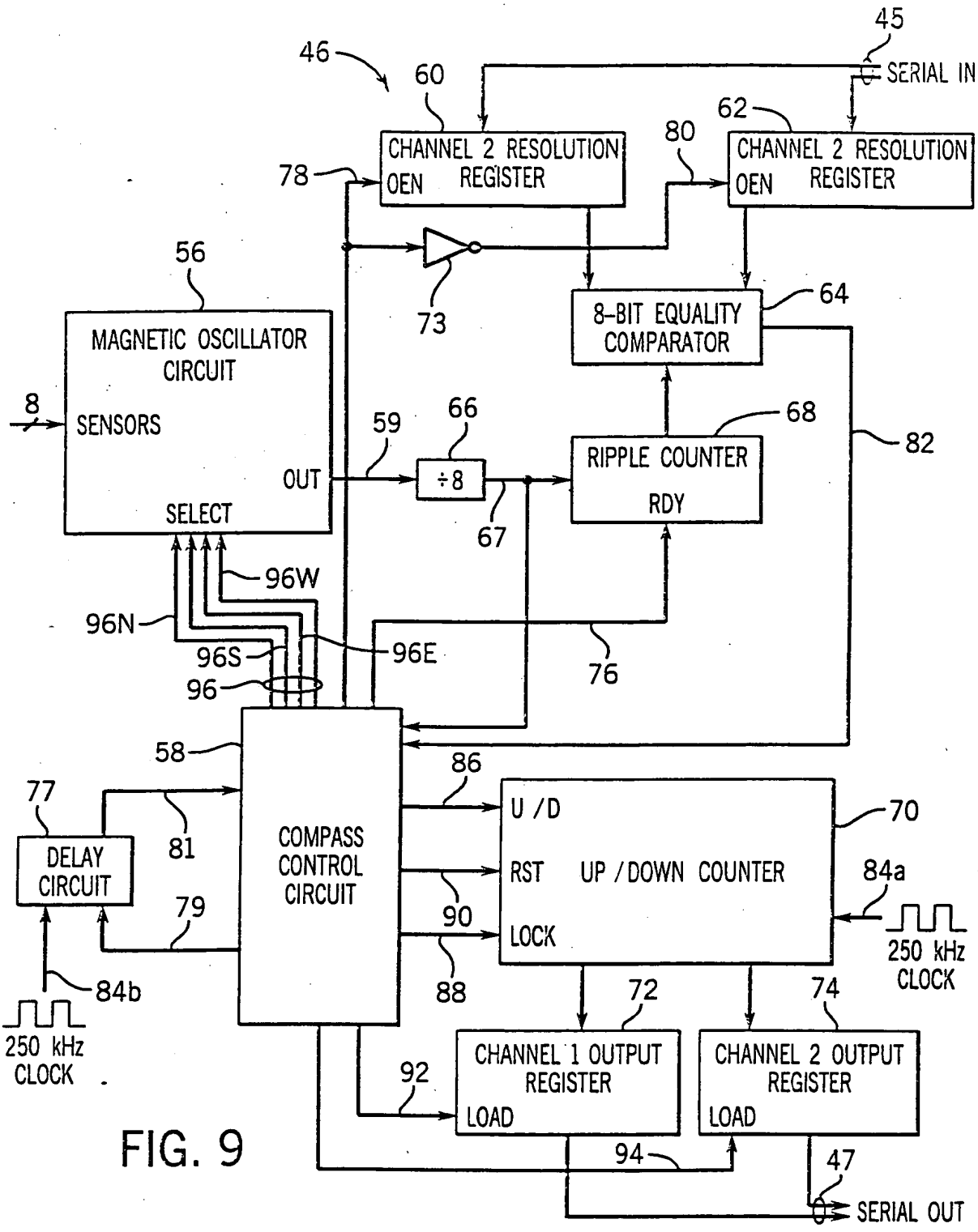

45
SERIAL IN
46
60
62
CHANNEL 2 RESOLUTION REGISTER
OEN
80
78
56
73
64
8-BIT EQUALITY COMPARATOR
MAGNETIC OSCILLATOR CIRCUIT
8
SENSORS
59
66
68
82
OUT
÷8
RIPPLE COUNTER
RDY
SELECT
67
96W
96N
96S
96E
96
76
58
86
77
U /D
70
DELAY CIRCUIT
81
COMPASS CONTROL CIRCUIT
RST
UP /DOWN COUNTER
84a
79
90
LOCK
250 kHz CLOCK
84b
88
72
74
250 kHz CLOCK
CHANNEL 1 OUTPUT REGISTER
CHANNEL 2 OUTPUT REGISTER
92
LOAD
LOAD
94
47
SERIAL OUT

FIG. 9

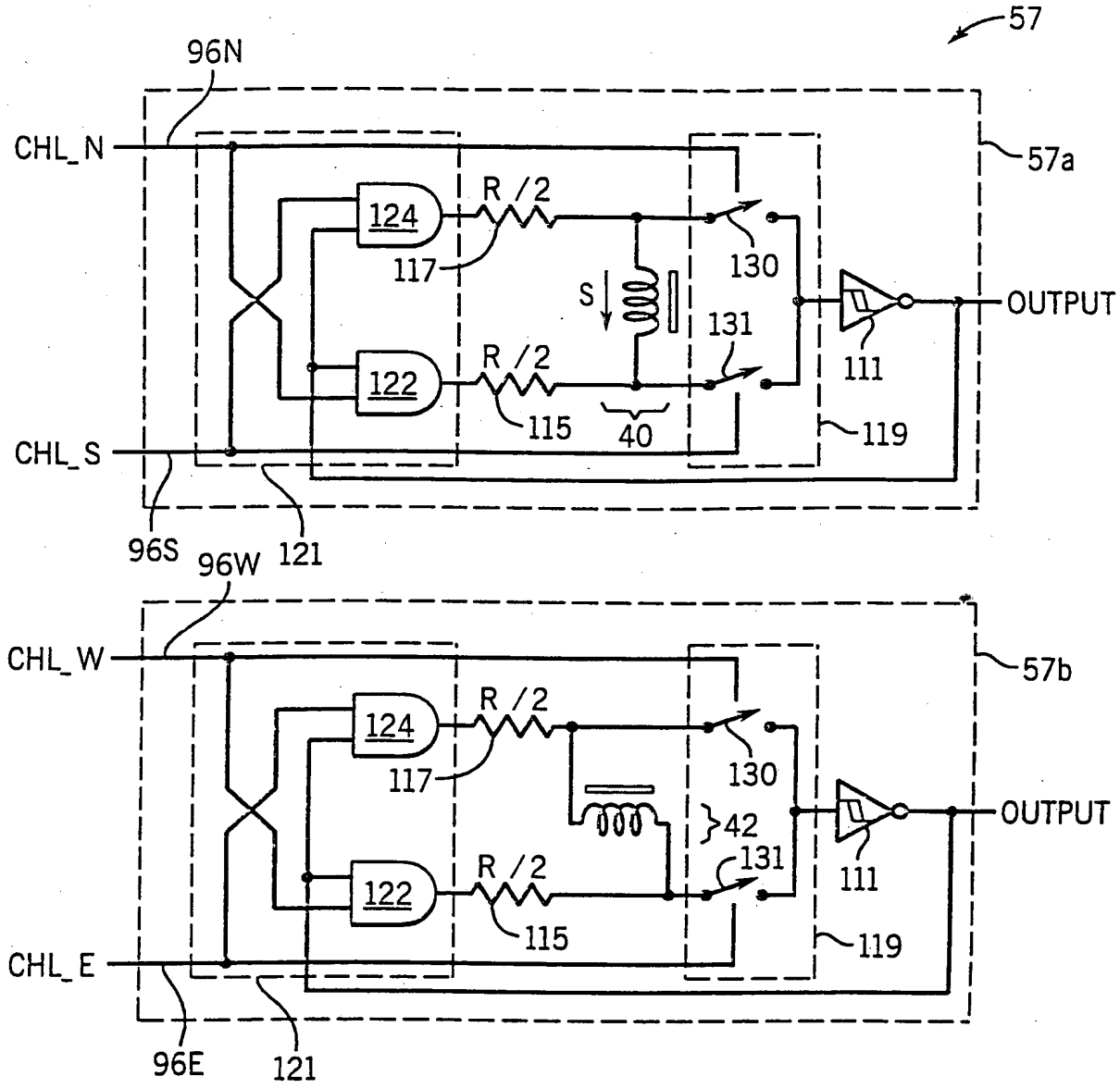

57
96N
CHL_N
57a
124
R /2
117
130
S
131
OUTPUT
122
R /2
111
115
40
119
CHL_S
96S
121
96W
CHL_W
57b
124
R /2
117
130
42
OUTPUT
131
122
R /2
111
115
119
CHL_E
96E
121

FIG. 10

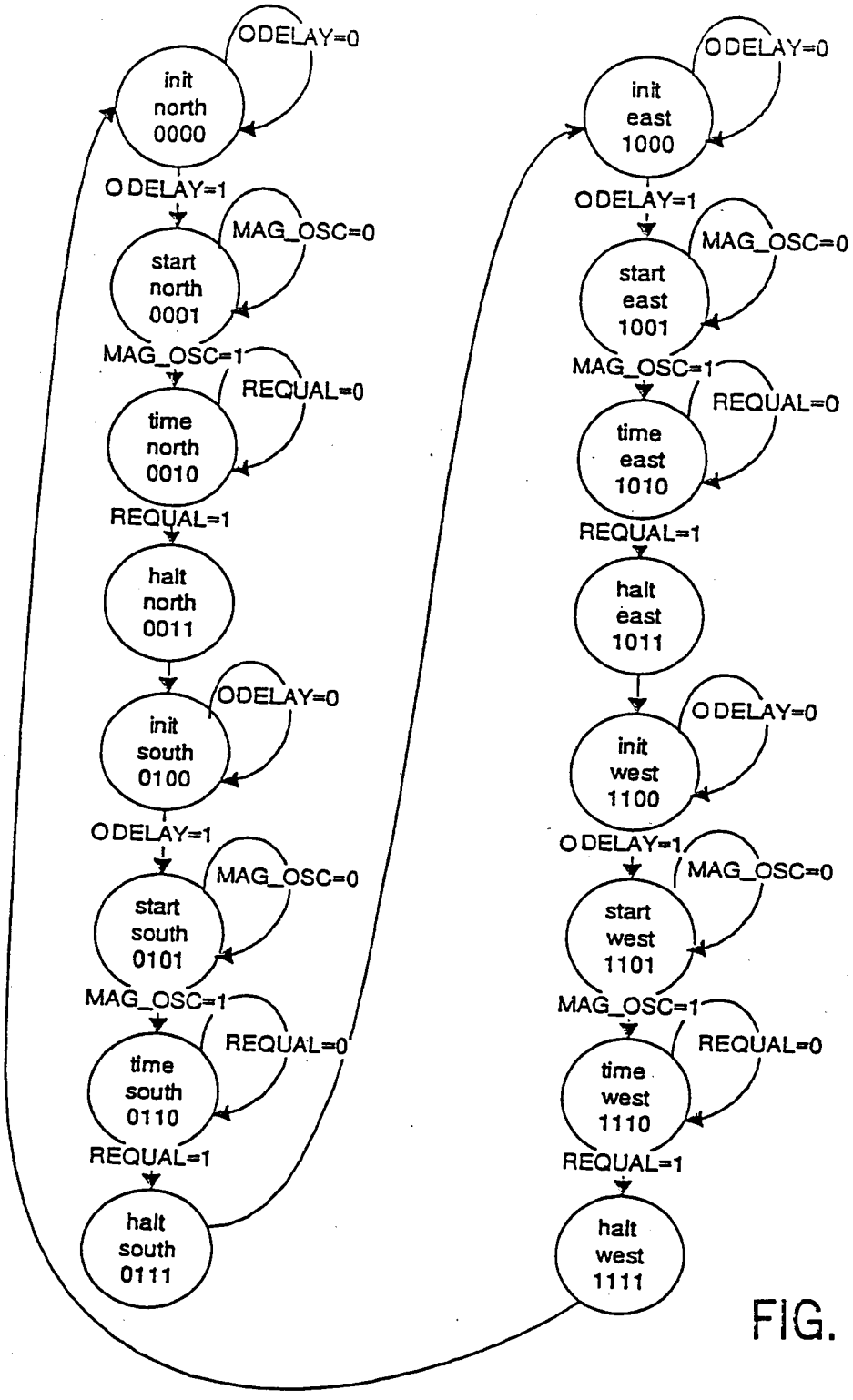

ODELAY=0
init north 0000
ODELAY=1
MAG_OSC=0
start north 0001
MAG_OSC=1
REQUAL=0
time north 0010
REQUAL=1
halt north 0011
ODELAY=0
init south 0100
ODELAY=1
MAG_OSC=0
start south 0101
MAG_OSC=1
REQUAL=0
time south 0110
REQUAL=1
halt south 0111
ODELAY=0
init east 1000
ODELAY=1
MAG_OSC=0
start east 1001
MAG_OSC=1
REQUAL=0
time east 1010
REQUAL=1
halt east 1011
ODELAY=0
init west 1100
ODELAY=1
MAG_OSC=0
start west 1101
MAG_OSC=1
REQUAL=0
time west 1110
REQUAL=1
halt west 1111

FIG. 11

COMPASS STATE MACHINE
STATE OUTPUT MATRIX

	STATE	DESCRIPTION	RCLEAR(1)	DELAY(1)	RENABLE_E(1)	CLEAR(0)	U /D(0)	ENABLE(1)	LATCH_N(0)	LATCH_E(0)	CHL_N(0)	CHL_S(0)	CHL_E(0)	CHL_W(0)
0	0000	INITIALIZE NORTH	1	0	1	0	0	1	0	0	1	0	0	0
1	0001	START NORTH	0	1	1	0	0	1	0	0	1	0	0	0
2	0010	START TIMING NORTH	0	1	1	1	0	0	0	0	1	0	0	0
3	0011	HALT TIMER	1	1	1	1	1	1	0	0	0	0	0	0
4	0100	INITIALIZE SOUTH	1	0	1	1	1	1	0	0	0	1	0	0
5	0101	START SOUTH	0	1	1	1	1	1	0	0	0	1	0	0
6	0110	START TIMING SOUTH	0	1	1	1	1	0	0	0	0	1	0	0
7	0111	HALT TIMER	1	1	1	1	0	1	1	0	0	0	0	0
8	1000	INITIALIZE EAST	1	0	0	0	0	1	0	0	0	0	1	0
9	1001	START EAST	0	1	0	0	0	1	0	0	0	0	1	0
10	1010	START TIMING EAST	0	1	0	1	0	0	0	0	0	0	1	0
11	1011	HALT TIMER	1	1	0	1	1	1	0	0	0	0	0	0
12	1100	INITIALIZE WEST	1	0	0	1	1	1	0	0	0	0	0	1
13	1101	START WEST	0	1	0	1	1	1	0	0	0	0	0	1
14	1110	START TIMING WEST	0	1	0	1	1	0	0	0	0	0	0	1
15	1111	HALT TIMER	1	1	0	1	0	1	0	1	0	0	0	0

FIG. 12

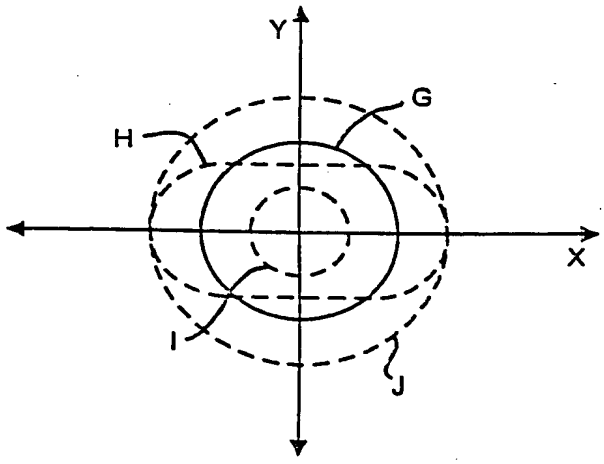


FIG. 13

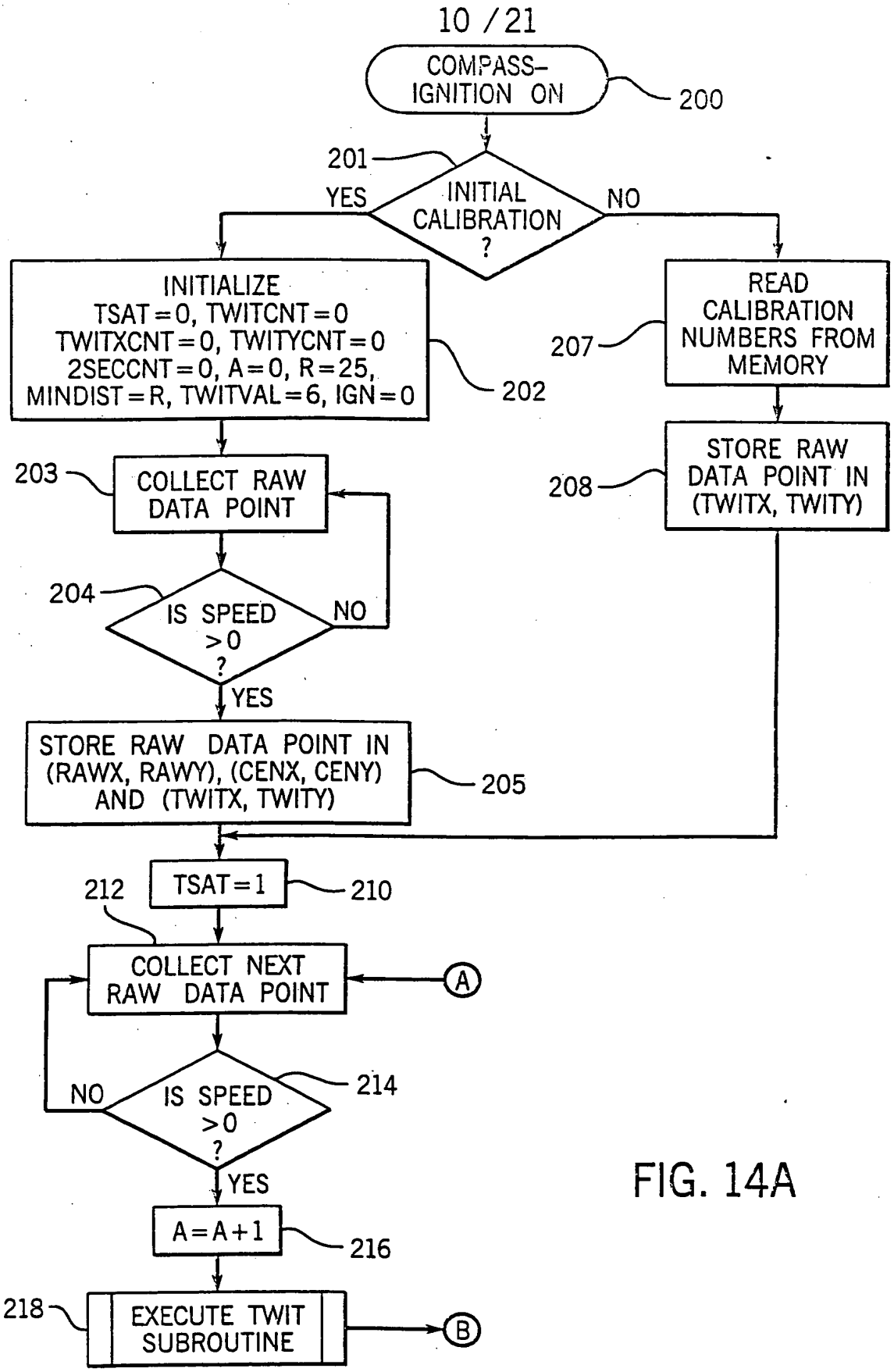

COMPASS–
IGNITION ON
200
201
INITIAL
CALIBRATION
?
YES
NO
INITIALIZE
TSAT=0, TWITCNT=0
TWITXCNT=0, TWITYCNT=0
2SECCNT=0, A=0, R=25,
MINDIST=R, TWITVAL=6, IGN=0
202
READ
CALIBRATION
NUMBERS FROM
MEMORY
207
STORE RAW
DATA POINT IN
(TWITX, TWITY)
208
203
COLLECT RAW
DATA POINT
204
IS SPEED
>0
?
NO
YES
STORE RAW DATA POINT IN
(RAWX, RAWY), (CENX, CENY)
AND (TWITX, TWITY)
205
212
TSAT=1
210
COLLECT NEXT
RAW DATA POINT
A
NO
IS SPEED
>0
?
214
YES
A=A+1
216
218
EXECUTE TWIT
SUBROUTINE
B

FIG. 14A

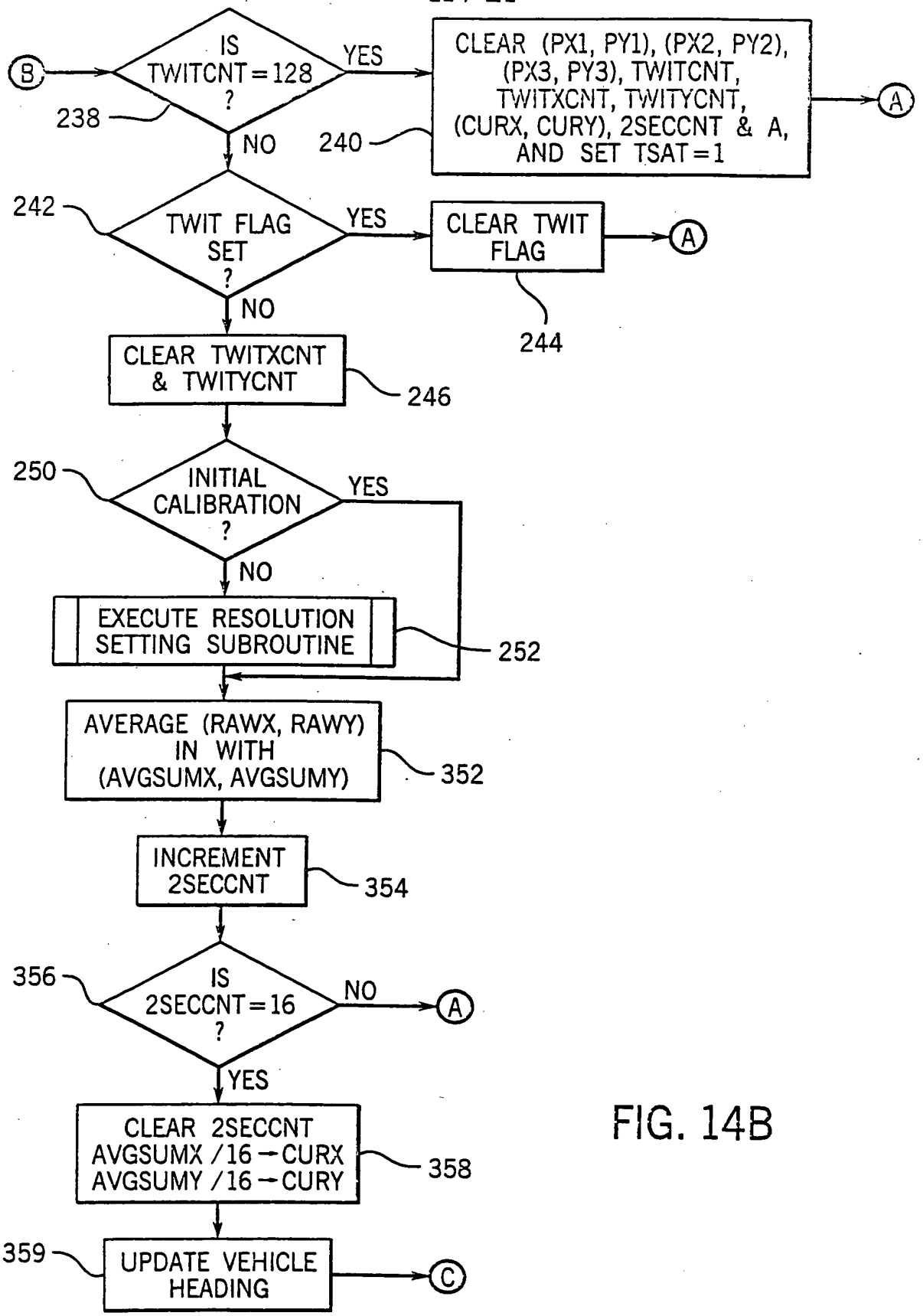

B
IS TWITCNT = 128 ?
YES
238
NO
240
CLEAR (PX1, PY1), (PX2, PY2), (PX3, PY3), TWITCNT, TWITXCNT, TWITYCNT, (CURX, CURY), 2SECCNT & A, AND SET TSAT = 1
A
242
TWIT FLAG SET ?
YES
CLEAR TWIT FLAG
A
244
NO
CLEAR TWITXCNT & TWITYCNT
246
250
INITIAL CALIBRATION ?
YES
NO
EXECUTE RESOLUTION SETTING SUBROUTINE
252
AVERAGE (RAWX, RAWY) IN WITH (AVGSUMX, AVGSUMY)
352
INCREMENT 2SECCNT
354
356
IS 2SECCNT = 16 ?
NO
A
YES
CLEAR 2SECCNT
AVGSUMX / 16 → CURX
AVGSUMY / 16 → CURY
358
359
UPDATE VEHICLE HEADING
C

FIG. 14B

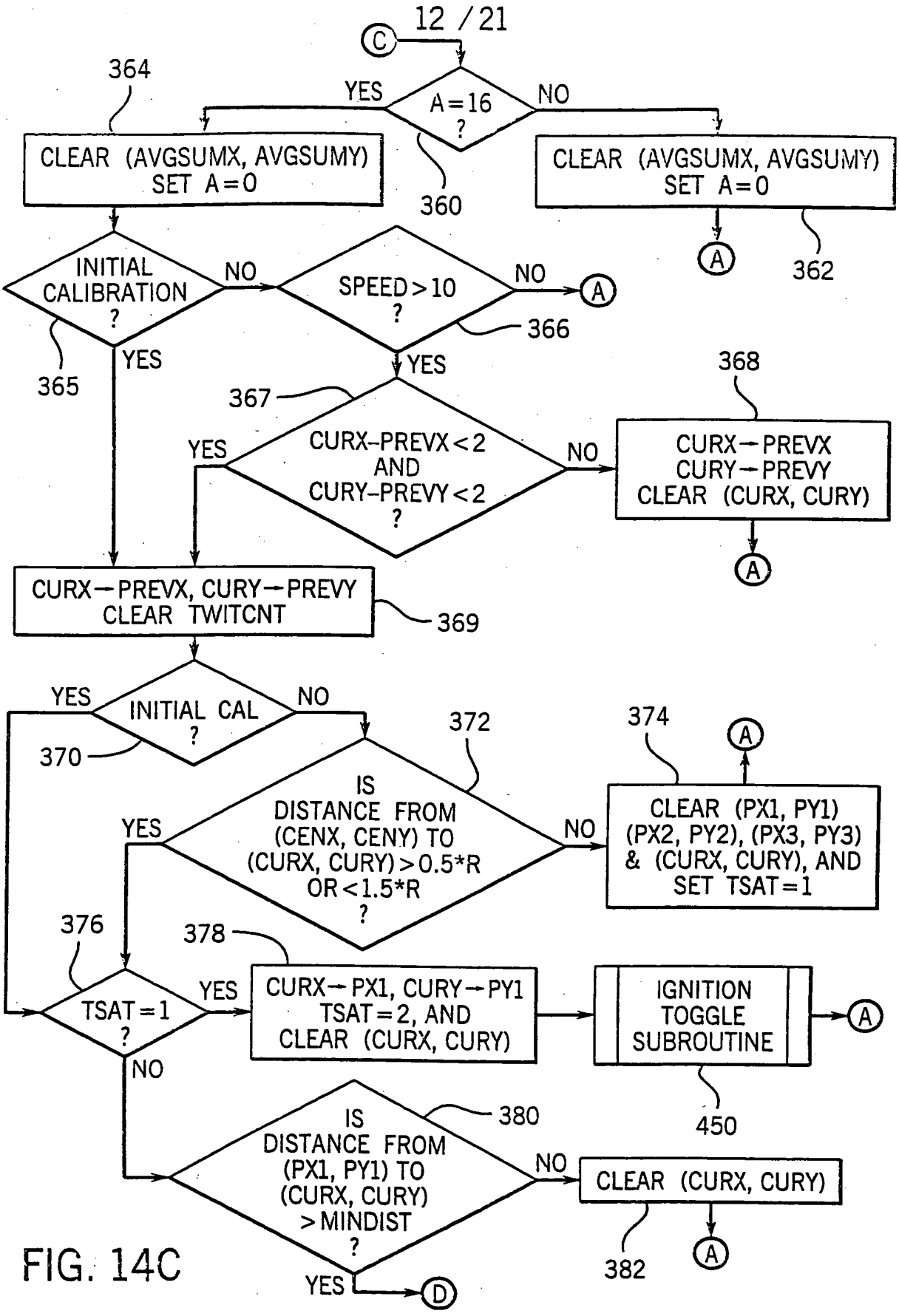

C
A=16 ?
YES
NO
364
CLEAR (AVGSUMX, AVGSUMY)
SET A=0
360
CLEAR (AVGSUMX, AVGSUMY)
SET A=0
A
362
INITIAL CALIBRATION ?
NO
SPEED>10 ?
NO
A
366
365
YES
YES
367
368
YES
CURX-PREVX<2 AND CURY-PREVY<2 ?
NO
CURX←PREVX
CURY←PREVY
CLEAR (CURX, CURY)
A
CURX←PREVX, CURY←PREVY
CLEAR TWITCNT
369
YES
INITIAL CAL ?
NO
370
372
374
A
IS DISTANCE FROM (CENX, CENY) TO (CURX, CURY)>0.5*R OR<1.5*R ?
YES
NO
CLEAR (PX1, PY1) (PX2, PY2), (PX3, PY3) & (CURX, CURY), AND SET TSAT=1
376
378
TSAT=1 ?
YES
CURX←PX1, CURY←PY1
TSAT=2, AND
CLEAR (CURX, CURY)
IGNITION TOGGLE SUBROUTINE
A
450
NO
380
IS DISTANCE FROM (PX1, PY1) TO (CURX, CURY) >MINDIST ?
NO
CLEAR (CURX, CURY)
382
A
YES
D

FIG. 14C

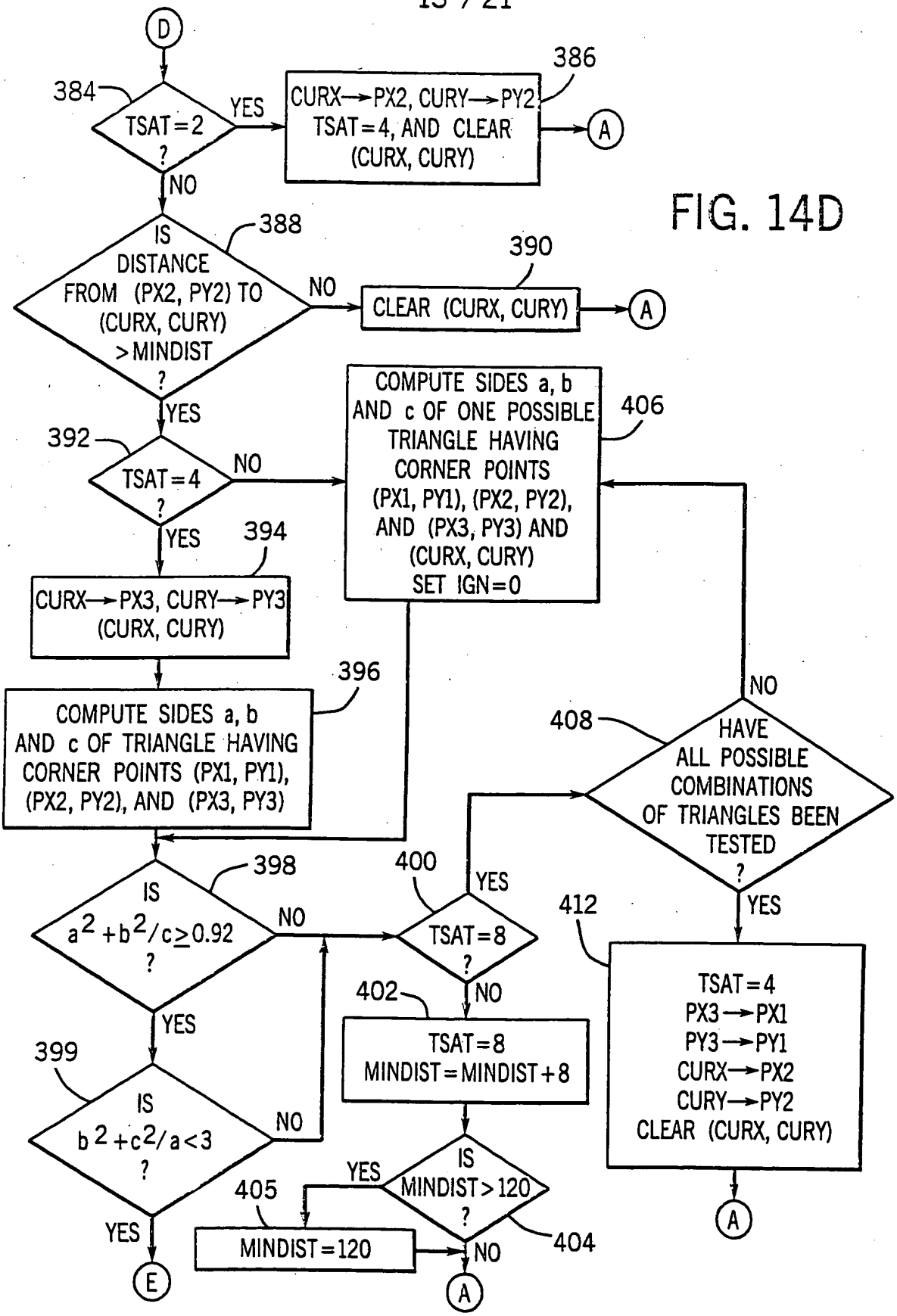

D
384
TSAT=2 ?
YES
386
CURX→PX2, CURY→PY2
TSAT=4, AND CLEAR
(CURX, CURY)
A
NO
388
IS DISTANCE FROM (PX2, PY2) TO (CURX, CURY) >MINDIST ?
NO
390
CLEAR (CURX, CURY)
A
YES
392
TSAT=4 ?
NO
406
COMPUTE SIDES a, b AND c OF ONE POSSIBLE TRIANGLE HAVING CORNER POINTS (PX1, PY1), (PX2, PY2), AND (PX3, PY3) AND (CURX, CURY)
SET IGN=0
YES
394
CURX→PX3, CURY→PY3
(CURX, CURY)
396
COMPUTE SIDES a, b AND c OF TRIANGLE HAVING CORNER POINTS (PX1, PY1), (PX2, PY2), AND (PX3, PY3)
NO
408
HAVE ALL POSSIBLE COMBINATIONS OF TRIANGLES BEEN TESTED ?
YES
412
TSAT=4
PX3→PX1
PY3→PY1
CURX→PX2
CURY→PY2
CLEAR (CURX, CURY)
A
398
IS $a^2+b^2/c \geq 0.92$?
NO
400
TSAT=8 ?
YES
NO
402
TSAT=8
MINDIST=MINDIST+8
YES
399
IS $b^2+c^2/a<3$?
NO
IS MINDIST>120 ?
YES
405
MINDIST=120
NO
404
YES
E
A

FIG. 14D

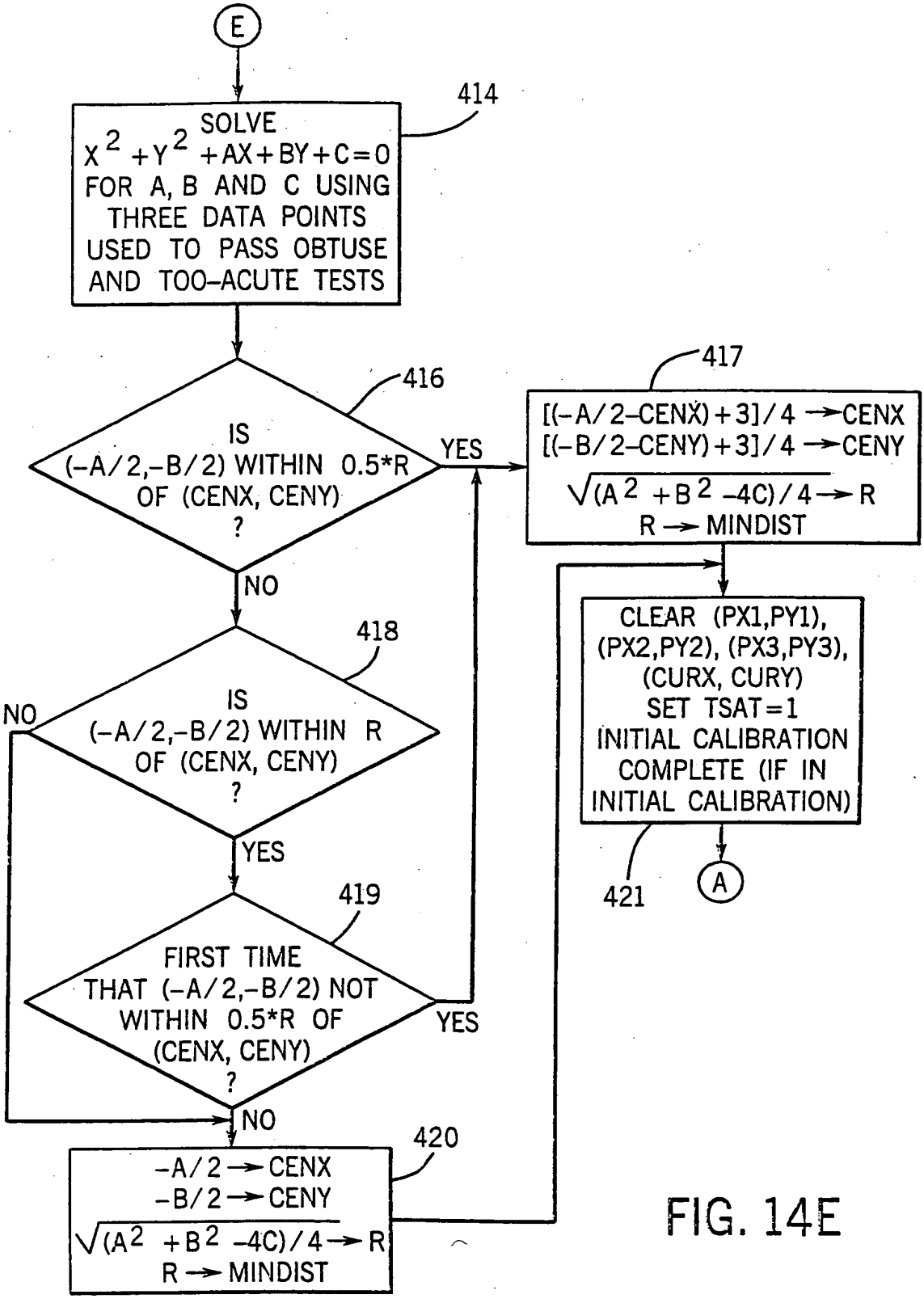

E
414
SOLVE
$X^2+Y^2+AX+BY+C=0$
FOR A, B AND C USING THREE DATA POINTS USED TO PASS OBTUSE AND TOO-ACUTE TESTS
416
IS (-A/2,-B/2) WITHIN 0.5*R OF (CENX, CENY) ?
YES
417
[(-A/2-CENX)+3]/4 → CENX
[(-B/2-CENY)+3]/4 → CENY
$\sqrt{(A^2+B^2-4C)/4}$ → R
R → MINDIST
NO
418
IS (-A/2,-B/2) WITHIN R OF (CENX, CENY) ?
NO
YES
419
FIRST TIME THAT (-A/2,-B/2) NOT WITHIN 0.5*R OF (CENX, CENY) ?
YES
NO
420
-A/2 → CENX
-B/2 → CENY
$\sqrt{(A^2+B^2-4C)/4}$ → R
R → MINDIST
CLEAR (PX1,PY1), (PX2,PY2), (PX3,PY3), (CURX, CURY)
SET TSAT=1
INITIAL CALIBRATION COMPLETE (IF IN INITIAL CALIBRATION)
421
A

FIG. 14E

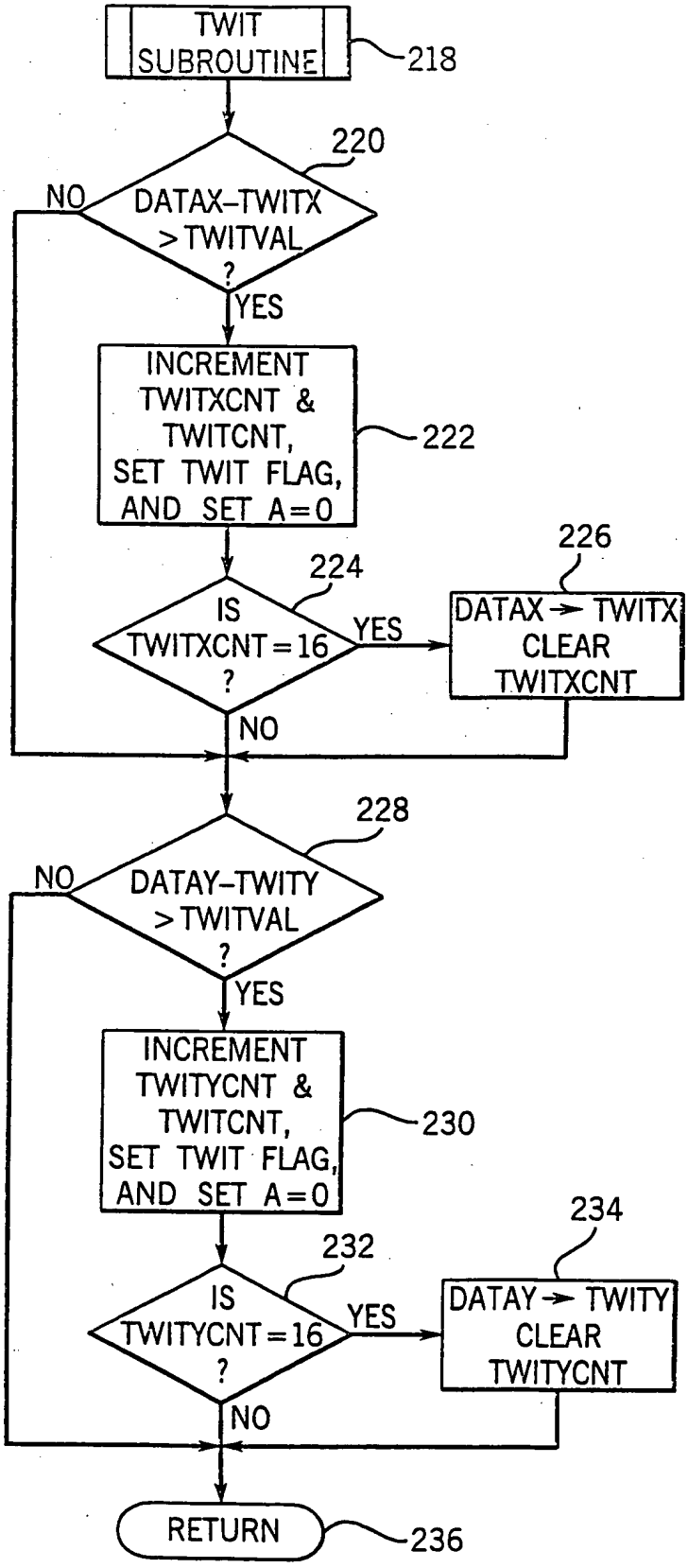
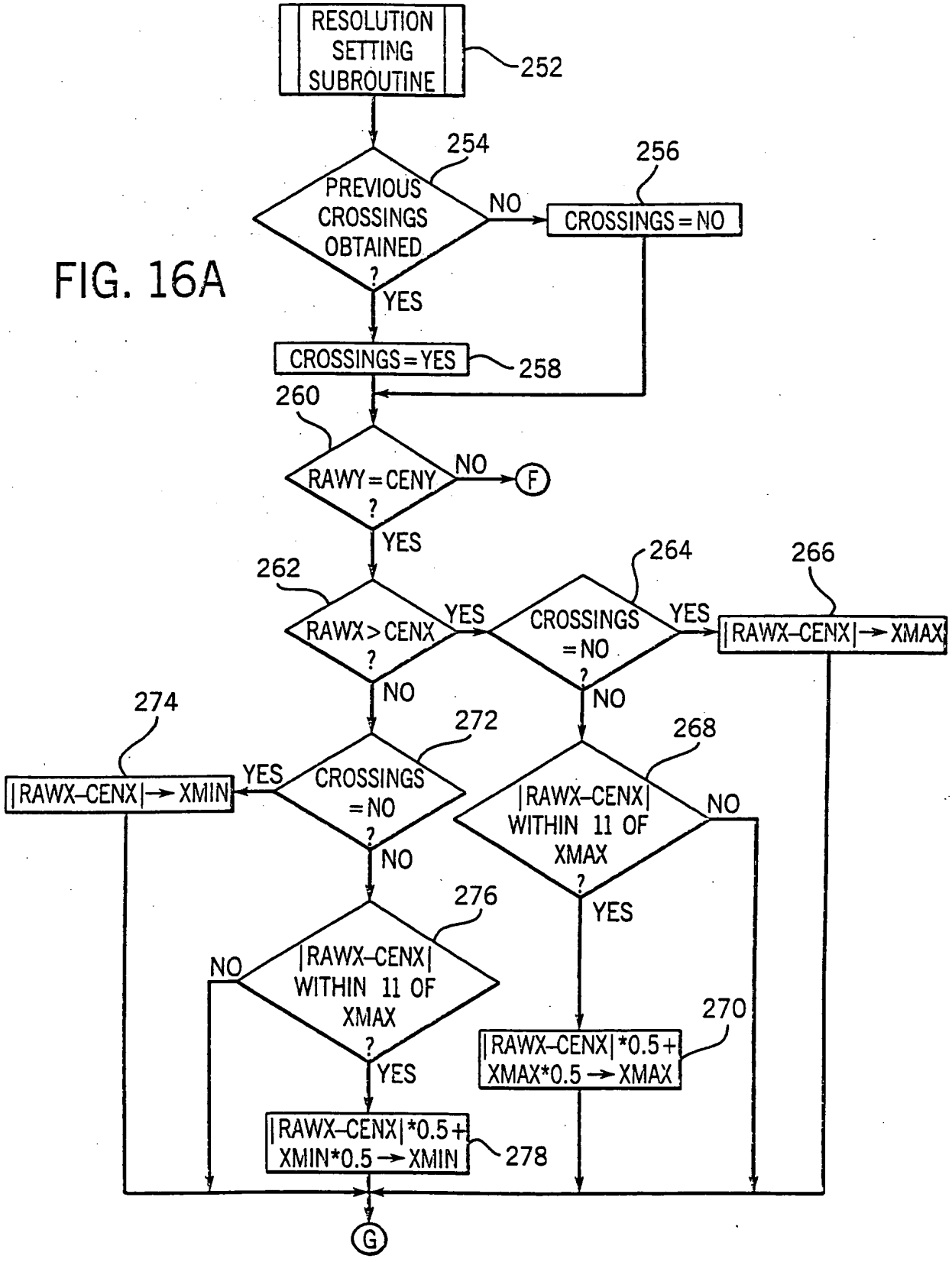

TWIT SUBROUTINE
218
220
NO
DATAX–TWITX > TWITVAL ?
YES
INCREMENT TWITXCNT & TWITCNT, SET TWIT FLAG, AND SET A=0
222
224
226
IS TWITXCNT=16 ?
YES
DATAX → TWITX CLEAR TWITXCNT
NO
228
NO
DATAY–TWITY > TWITVAL ?
YES
INCREMENT TWITYCNT & TWITCNT, SET TWIT FLAG, AND SET A=0
230
232
234
IS TWITYCNT=16 ?
YES
DATAY → TWITY CLEAR TWITYCNT
NO
RETURN
236

FIG. 15

FIG. 16A


RESOLUTION SETTING SUBROUTINE
252
254
PREVIOUS CROSSINGS OBTAINED ?
NO
256
CROSSINGS = NO
YES
CROSSINGS = YES
258
260
RAWY = CENY ?
NO
F
YES
262
RAWX > CENX ?
YES
264
CROSSINGS = NO ?
YES
266
|RAWX–CENX| → XMAX
NO
NO
274
|RAWX–CENX| → XMIN
YES
272
CROSSINGS = NO ?
268
|RAWX–CENX| WITHIN 11 OF XMAX ?
NO
NO
YES
276
|RAWX–CENX| WITHIN 11 OF XMAX ?
NO
YES
270
|RAWX–CENX|*0.5 + XMAX*0.5 → XMAX
|RAWX–CENX|*0.5 + XMIN*0.5 → XMIN
278
G

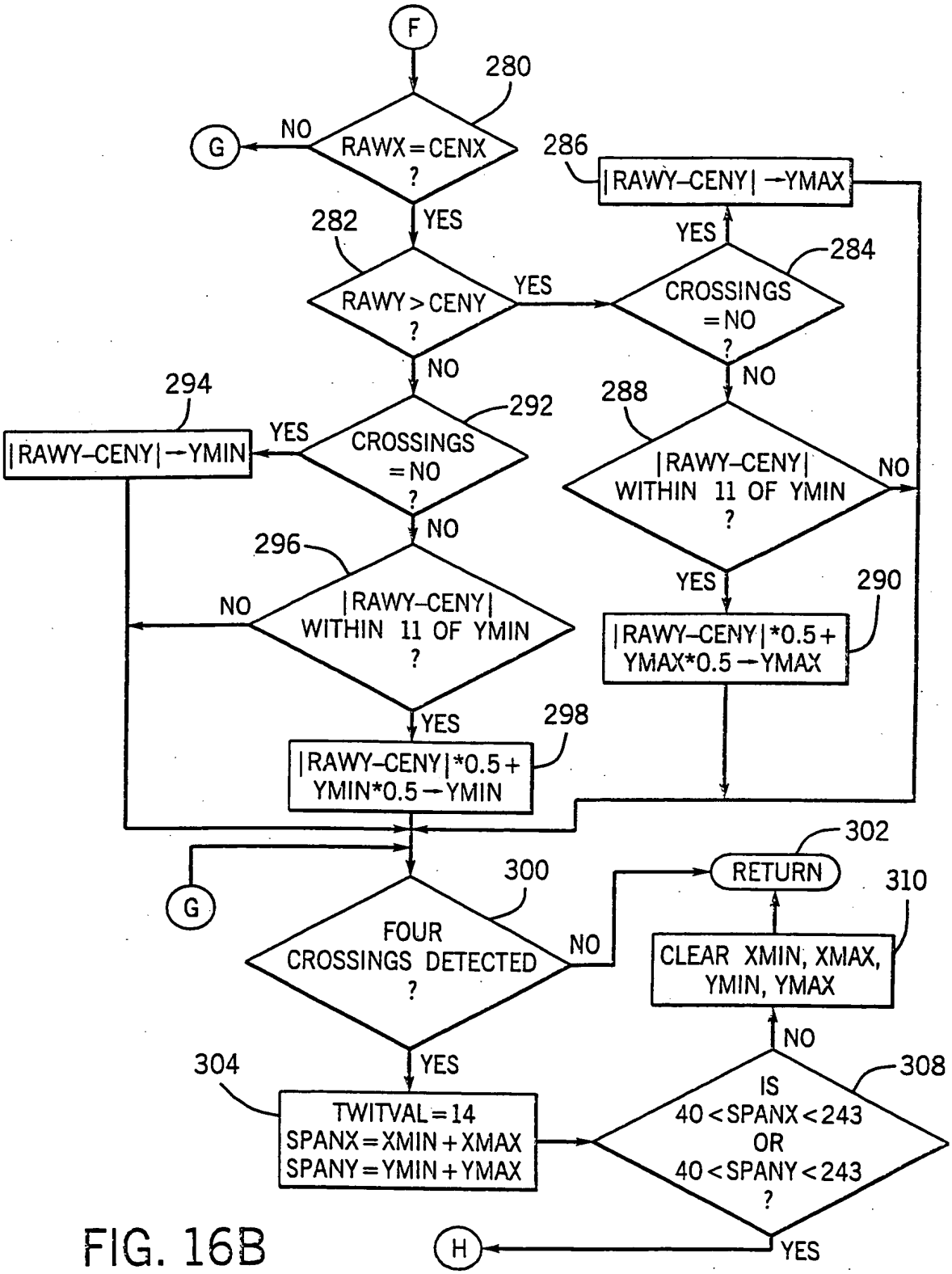

F
280
RAWX = CENX ?
NO
G
YES
282
RAWY > CENY ?
YES
NO
284
CROSSINGS = NO ?
YES
NO
286
|RAWY–CENY| –YMAX
288
|RAWY–CENY| WITHIN 11 OF YMIN ?
NO
YES
290
|RAWY–CENY|*0.5 + YMAX*0.5 – YMAX
292
CROSSINGS = NO ?
YES
NO
294
|RAWY–CENY| –YMIN
296
|RAWY–CENY| WITHIN 11 OF YMIN ?
NO
YES
298
|RAWY–CENY|*0.5 + YMIN*0.5 – YMIN
G
300
FOUR CROSSINGS DETECTED ?
NO
YES
302
RETURN
310
CLEAR XMIN, XMAX, YMIN, YMAX
NO
308
IS 40 < SPANX < 243 OR 40 < SPANY < 243 ?
YES
304
TWITVAL = 14
SPANX = XMIN + XMAX
SPANY = YMIN + YMAX
H

FIG. 16B

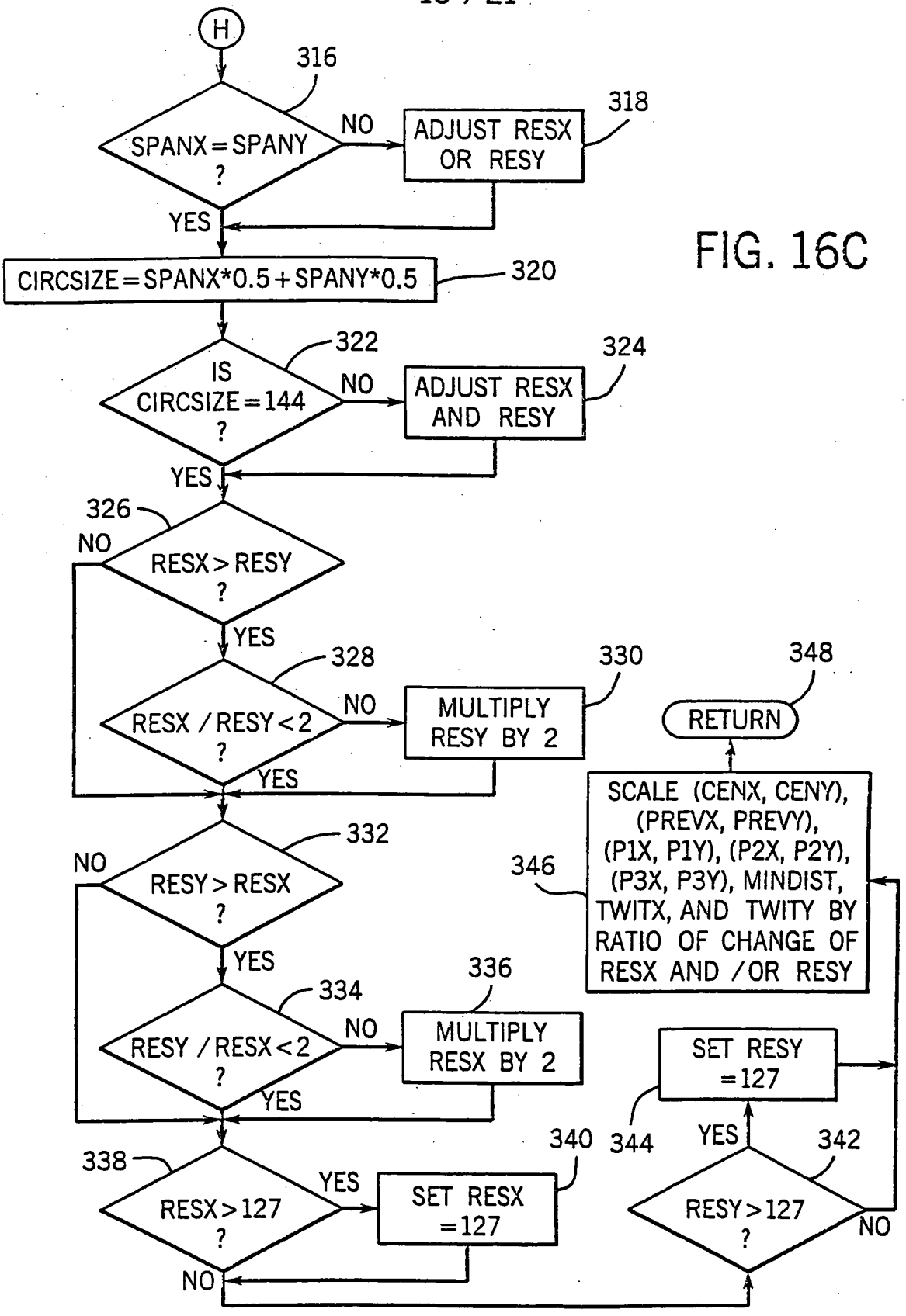

H
316
SPANX = SPANY ?
NO
318
ADJUST RESX OR RESY
YES
CIRCSIZE = SPANX*0.5 + SPANY*0.5
320
322
IS CIRCSIZE = 144 ?
NO
324
ADJUST RESX AND RESY
YES
326
NO
RESX > RESY ?
YES
328
RESX / RESY < 2 ?
NO
330
MULTIPLY RESY BY 2
YES
332
NO
RESY > RESX ?
YES
334
RESY / RESX < 2 ?
NO
336
MULTIPLY RESX BY 2
YES
338
RESX > 127 ?
YES
340
SET RESX = 127
NO
344
YES
342
RESY > 127 ?
NO
SET RESY = 127
346
SCALE (CENX, CENY), (PREVX, PREVY), (P1X, P1Y), (P2X, P2Y), (P3X, P3Y), MINDIST, TWITX, AND TWITY BY RATIO OF CHANGE OF RESX AND / OR RESY
348
RETURN

FIG. 16C

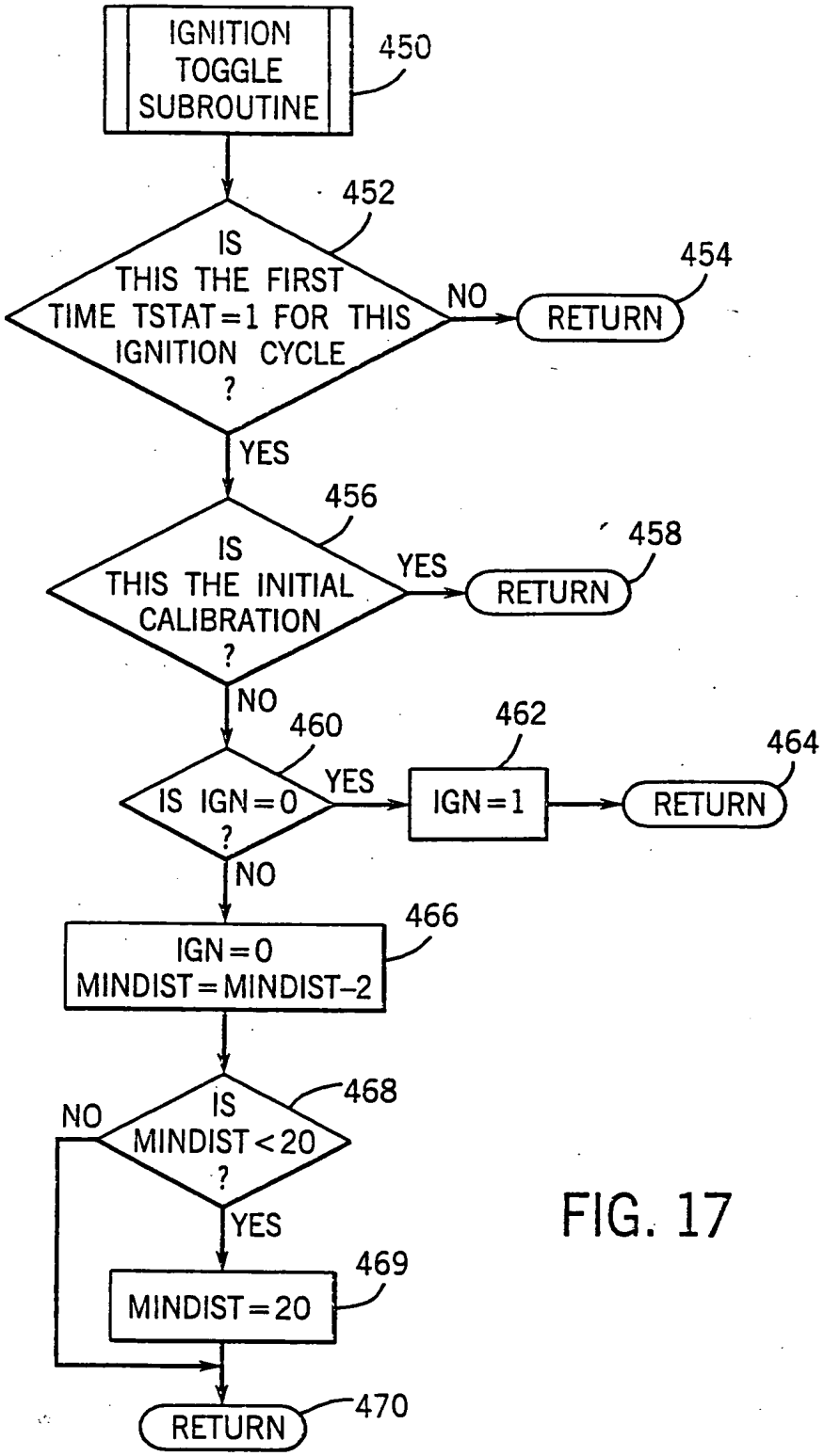

IGNITION TOGGLE SUBROUTINE
450
452
IS THIS THE FIRST TIME TSTAT=1 FOR THIS IGNITION CYCLE ?
NO
454
RETURN
YES
456
IS THIS THE INITIAL CALIBRATION ?
YES
458
RETURN
NO
460
IS IGN=0 ?
YES
462
IGN=1
464
RETURN
NO
466
IGN=0
MINDIST=MINDIST-2
468
IS MINDIST<20 ?
NO
YES
469
MINDIST=20
470
RETURN

FIG. 17

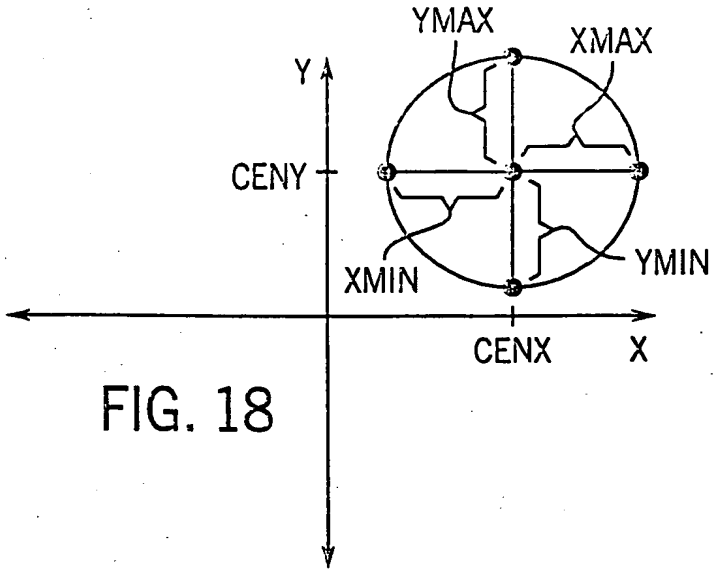


FIG. 18

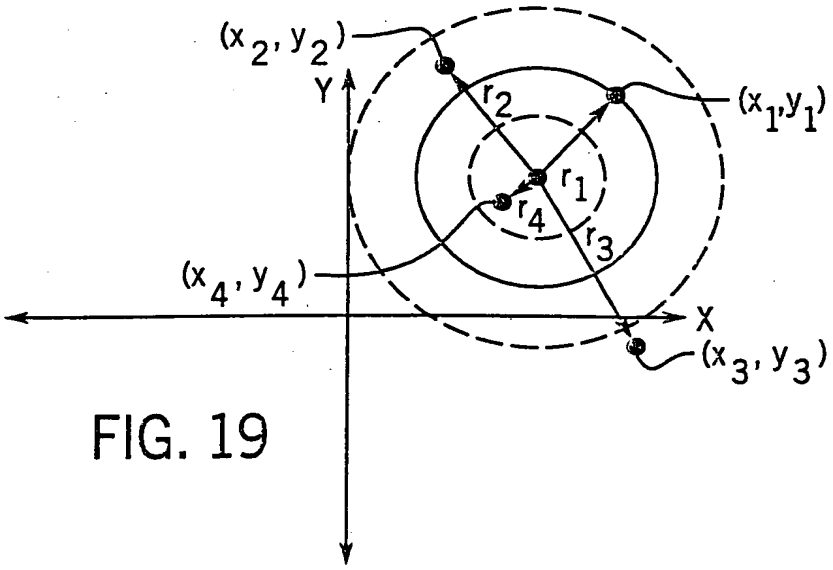


FIG. 19

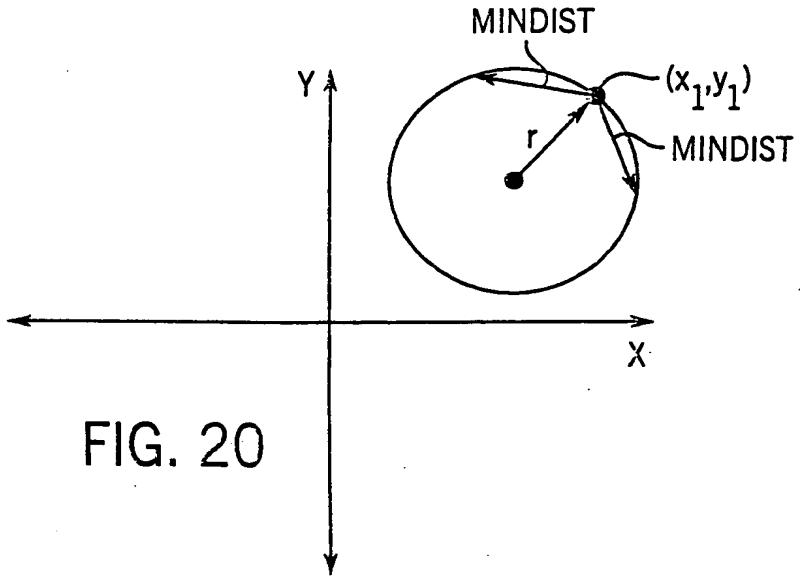


FIG. 20

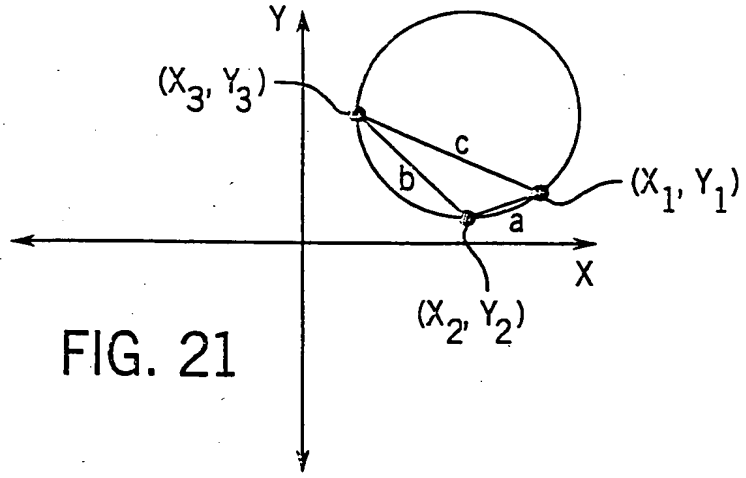


FIG. 21

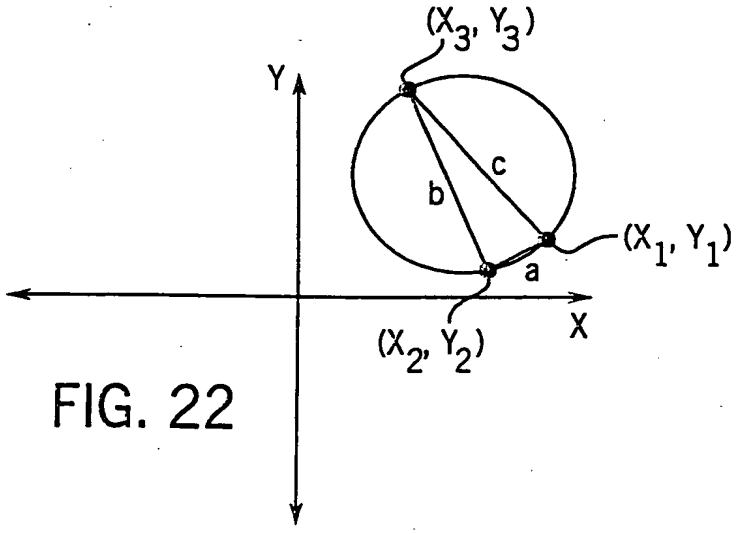


FIG. 22

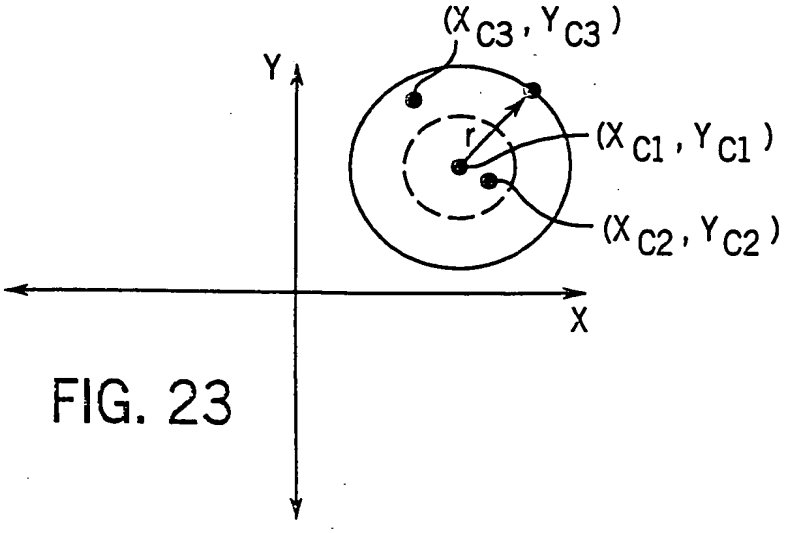


FIG. 23